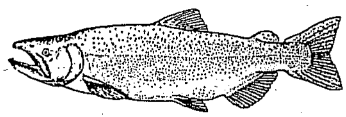
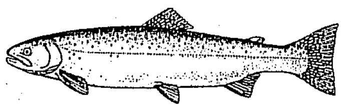
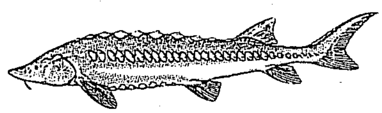
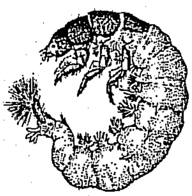
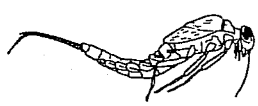
IDENTIFICATION OF THE INSTREAM FLOW REQUIREMENTS FOR ANADROMOUS FISH IN THE STREAMS WITHIN THE CENTRAL VALLEY OF CALIFORNIA

Annual Progress Report
Fiscal Year 2005

U.S. Fish and Wildlife Service
Sacramento Fish and Wildlife Office
2800 Cottage Way, Room W-2605
Sacramento, California 95825

Prepared by staff of
The Energy Planning and Instream Flow Branch

PREFACE

The following is the fourth annual progress report prepared as part of the Central Valley Project Improvement Act Instream Flow Investigations, a 6-year effort which began in October, 2001.[1] Title 34, Section 3406(b)(1)(B) of the Central Valley Project Improvement Act, P.L. 102-575, requires the Secretary of the Department of the Interior to determine instream flow needs for anadromous fish for all Central Valley Project controlled streams and rivers, based on recommendations of the U.S. Fish and Wildlife Service (Service) after consultation with the California Department of Fish and Game (CDFG). The purpose of this investigation is to provide reliable scientific information to the Service's Central Valley Project Improvement Act Program to be used to develop such recommendations for Central Valley streams and rivers.

The field work described herein was conducted by Ed Ballard, Mark Gard, Bill Pelle, Rick Williams, Matt McCormack, Laurie Stafford, Brandon Thompson, Sarah Giovannetti, Ethan Jankowski, Jimmy Faulkner, Tim Loux, Lael Will, Felipe Carillo, Robert Feamster, Andy Hill, Debbie Giglio, and Rich DeHaven.

Written comments or questions about this report or these investigations should be submitted to:

Ed Ballard, Fishery Biologist
Energy Planning and Instream Flow Branch
U.S. Fish and Wildlife Service
Sacramento Fish and Wildlife Office
2800 Cottage Way, Room W-2605
Sacramento, California 95825

[1] This program is a continuation of a 7-year effort, also titled the Central Valley Project Improvement Act Instream Flow Investigations, which ran from February 1995 through September 2001.

INTRODUCTION

In response to substantial declines in anadromous fish populations, the Central Valley Project Improvement Act requires the doubling of the natural production of anadromous fish stocks, including the four races of chinook salmon (fall, late-fall, winter, and spring), steelhead trout, and white and green sturgeon. In June 2001, the Service's Sacramento Fish and Wildlife Office, Energy Planning and Instream Flow Branch prepared a study proposal to use the Service's Instream Flow Incremental Methodology (IFIM) to identify the instream flow requirements for anadromous fish in selected streams within the Central Valley of California. The proposal included completing instream flow studies on the Sacramento and Lower American Rivers and Butte Creek which had begun under the previous 7-year effort, and conducting instream flow studies on other rivers, with the Yuba River selected as the next river for studies. The last report for the Lower American River study was completed in February 2003 and the final report for the Butte Creek study was completed in September 2003. In 2004, Clear Creek was selected as an additional river for studies.

The Sacramento River study was planned to be a 7-year effort originally scheduled to be concluded in September 2001. Specific goals of the study were to determine the relationship between streamflow and physical habitat availability for all life stages of chinook salmon (fall, late-fall, winter-runs) and to determine the relationship between streamflow and redd dewatering and juvenile stranding. The study components included: 1) compilation and review of existing information; 2) consultation with other agencies and biologists; 3) field reconnaissance; 4) development of habitat suitability criteria (HSC); 5) study site selection and transect placement; 6) hydraulic and structural data collection; 7) construction and calibration of reliable hydraulic simulation models; 8) construction of habitat models to predict physical habitat availability over a range of river discharges; and 9) preparation of draft and final reports. The first seven study components were completed by October 2004. The Fiscal Year (FY) 2005 Scope of Work (SOW) identified study tasks to be undertaken. These included: construction of habitat models to predict physical habitat availability over a range of river discharges and preparation of draft and final reports (study components 8 and 9).

The Yuba River study is a 4-year effort, the goals of which are to determine the relationship between stream flow and physical habitat availability for all life stages of chinook salmon (fall- and spring-runs) and steelhead/rainbow trout and to identify flows at which redd dewatering and juvenile stranding conditions occur. The study started with the location and counting of spring-run chinook salmon redds during September 2001 and the collection of fall-run chinook salmon spawning HSC during November-December 2001. Collection of spawning criteria data for fall- and spring-run chinook salmon and steelhead/rainbow trout was completed by April 2004. Field work to determine the relationship between habitat availability (spawning) and streamflow for spring-run and fall-run chinook salmon and steelhead/rainbow trout was completed in FY 2005. This field work included hydraulic and structural data collection. In FY 2004, field work to determine the relationship between habitat availability (juvenile rearing) and streamflow for spring-run and fall-run chinook salmon and steelhead/rainbow trout was conducted on the study sites selected in FY 2003. In addition, the process of gathering HSC data for juvenile rearing continued.

The Clear Creek study is a 5-year effort, the goals of which are to determine the relationship between stream flow and physical habitat availability for all life stages of chinook salmon (fall- and spring-run) and steelhead/rainbow trout. There will be three phases to this study based on the life stages to be studied and the number of reaches delineated for Clear Creek from downstream of Whiskeytown Reservoir to the confluence with the Sacramento River[2]. Spawning habitat study sites for the first phase of the study were selected that encompassed the upper two reaches of the creek. Field work to determine the relationship between habitat availability (spawning) and streamflow for spring-run chinook salmon and steelhead/rainbow trout was completed on the study sites selected in FY 2004. This field work included hydraulic and structural data collection. In addition, staff of the Service's Red Bluff Fish and Wildlife Office have been collecting HSC data for spring-run chinook salmon and steelhead/rainbow trout spawning.

The following sections summarize project activities between October 2004 and September 2005.

SACRAMENTO RIVER

Hydraulic Model Construction and Calibration

Chinook salmon spawning habitat

The topographic data for the 2-D model (contained in bed files) is first processed using the R2D_Bed software, where breaklines are added to produce a smooth bed topography. The resulting data set is then converted into a computational mesh using the R2D_Mesh software, with mesh elements sized to reduce the error in bed elevations resulting from the mesh-generating process to 0.1 foot where possible, given the computational constraints on the number of nodes. The resulting mesh is used in River2D to simulate depths and velocities at the flows to be simulated.

The Physical Habitat System (PHABSIM) transect at the downstream end of each site is calibrated to provide the Water Surface Elevation's (WSEL) at the downstream end of the site used by River2D. The PHABSIM transect at the upstream end of the site is calibrated to provide the water surface elevations used to calibrate the River2D model. The initial bed roughnesses

---

[2] There are three reaches: the upper alluvial reach, the canyon reach, and the lower alluvial reach. Spring-run chinook salmon and steelhead spawn in the upper two reaches, while fall-run chinook salmon spawn in the lower reach.

used by River2D are based on the observed substrate sizes and cover types. A multiplier is applied to the resulting bed roughnesses, with the value of the multiplier adjusted so that the WSEL generated by River2D at the upstream end of the site match the WSEL predicted by the PHABSIM transect at the upstream end of the site[3]. The River2D model is run at the flows at which the validation data set was collected, with the output used in GIS to determine the difference between simulated and measured velocities, depths, bed elevations, substrate and cover. The River2D model is also run at the simulation flows to use in computing habitat.

Construction and calibration of the 2-D models and production runs for all of the simulation flows were completed for all six study sites located between Battle Creek and Deer Creek in FY 2005.

Juvenile chinook salmon rearing habitat

Construction and calibration of the 2-D models and production runs for all of the simulation flows were already previously completed for all 17 juvenile rearing study sites located between Keswick Dam and Battle Creek in FY 2004.

Habitat Suitability Criteria Development

Juvenile chinook salmon rearing

Data collection for fry and juvenile rearing criteria was completed in FY 2001. Development of fry and juvenile rearing criteria was completed in FY 2003.

Chinook salmon spawning

HSC data were not collected for the six study sites on the Sacramento River between Battle Creek and Deer Creek. HSC previously developed by the Service on the Sacramento River for fall-run chinook salmon spawning (U.S. Fish and Wildlife Service 2003) were used for these sites.

Macroinvertebrate criteria

We have developed a second set of juvenile chinook salmon HSC - one based on food supply rather than physical habitat. Specifically, we developed HSC in FY 2005 for macroinvertebrate biomass and diversity. The criteria we developed were run on the juvenile rearing site habitat models to predict the relationship between flow and habitat area for macroinvertebrate biomass and diversity. We completed our sampling for macroinvertebrate criteria in FY 2001, with a total of 75 macroinvertebrate samples (22 in riffles, 20 in runs, 13 in pools and 20 in glides).

---

[3] This is the primary technique used to calibrate the River2D model.

Processing of samples, and computation of biomass and diversity represented by each sample, was completed under contract in July of 2004. HSC were developed in FY 2005 for macroinvertebrate production and diversity as determined by depth, velocity, and substrate size based on the biomass and diversity determined for the samples. Statistical analysis found that the 75 samples collected were sufficient to generate HSC. These criteria were applied to the 2-D modeling results of the rearing sites between Keswick Dam and Battle Creek to generate flow-habitat relationships. Peer review of the draft report has been completed and a response to comments document is being prepared. The final report and response to comments document will be issued by December 2005.

Habitat Simulation

Juvenile chinook salmon rearing

Using the Sacramento River juvenile chinook salmon rearing criteria developed in FY 2003, computation of rearing habitat over a range of discharges was completed in FY 2005 for all of the 17 rearing sites. A draft report on flow-habitat relationships for fall, late-fall and winter-run chinook salmon rearing between Keswick Reservoir and Battle Creek was completed by the end of December 2004. Peer review of the draft report and preparation of a response to comments document was completed in FY 2005. The final report was issued with the response to comments document in FY 2005.

Chinook salmon spawning

Fall-run chinook salmon spawning habitat were computed over a range of discharges in FY 2005 for the six study sites between Battle Creek and Deer Creek. After completing the initial draft report, peer review was conducted and a response to comments document prepared. The final report was completed and issued with the response to comments document in FY 2005[4].

Chinook salmon and steelhead juvenile stranding and redd dewatering

Stranding flows have been determined for all of the 108 juvenile chinook salmon stranding sites. Stranding areas have been determined for all of the 108 stranding sites.

Using the HSC previously developed by the Service on the Sacramento River for fall, late-fall, and winter-run chinook salmon spawning (U.S. Fish and Wildlife Service 2003) and on the lower American River for steelhead (U.S Fish and Wildlife Service 2000), the percent loss of spawning habitat area versus flow was computed for chinook salmon (fall, late-fall, spring-run) and steelhead over a range of discharges. The redd dewatering analysis was conducted using data from the 2-D models for our eight spawning sites from Keswick Dam to Battle Creek (Lower

---

[4] A final report on spawning between Keswick Dam and Battle Creek was issued in February 2003.

Lake Redding, Upper Lake Redding, Salt Creek, Bridge Riffle, Posse Grounds, Above Hawes Hole, Powerline Riffle and Price Riffle). Information on these sites is given in U.S. Fish and Wildlife Service 1999. A draft report is being prepared and the final report on the juvenile chinook salmon and steelhead stranding sites and redd dewatering analysis will be completed and issued by April 2006.

YUBA RIVER

Hydraulic and Structural Data Collection

Chinook salmon and steelhead/rainbow trout spawning

Hydraulic and structural data collection for all 10 spawning study sites was completed in FY 2004.

Juvenile chinook salmon and steelhead/rainbow trout rearing

Hydraulic and structural data collection continued in FY 2005. The data collected at the inflow and outflow transects include: 1) WSEL, measured to the nearest 0.01 foot at a minimum of three significantly different stream discharges using standard surveying techniques (differential leveling); 2) wetted streambed elevations determined by subtracting the measured depth from the surveyed WSEL at a measured flow; 3) dry ground elevations to points above bankfull discharge surveyed to the nearest 0.1 foot; 4) mean water column velocities measured at a mid-to-high-range flow at the points where bed elevations were taken; and 5) substrate and cover classification at these same locations (Tables 1 and 2) and also where dry ground elevations were surveyed. Data collected between the transects include: 1) bed elevation; 2) northing and easting (horizontal location); 3) cover; and 4) substrate. These parameters are collected at enough points to characterize the bed topography, substrate and cover of the site.

We have used two techniques to collect the data between the up- and downstream transects: 1) for areas that were dry or shallow (less than 3 feet), bed elevation and horizontal location of individual points were obtained with a total station, while the cover and substrate were visually assessed at each point; and 2) in portions of the site with depths greater than 3 feet, the Acoustic Doppler Current Profiler (ADCP) was used in concert with the total station to obtain bed elevation and horizontal location. Specifically, the ADCP was run across the channel at 50 to 150-foot intervals, with the initial and final horizontal location of each run measured by the total station. The WSEL of each ADCP run was measured with the level before starting the run. The WSEL of each run is then used together with the depths from the ADCP to determine the bed elevation of each point along the run. Velocities at each point measured by the ADCP will be used to validate the 2-D model. To validate the velocities predicted by the 2-D model for shallow areas within a site, depth, velocities, substrate and cover measurements were collected along the right and left banks within each site by wading with a wading rod equipped with a

Marsh-McBirney^R model 2000 or a Price AA velocity meter. The horizontal locations and bed elevations were determined by taking a total station shot on a prism held at each point where depth and velocity were measured. A minimum of 25 representative points were measured along the length of each side of the river per site.

Water surface elevations have been measured at low, medium, and high flows for all eight study sites. Discharge measurements for the above WSELs were made at Diversion, Whirlpool, and Side-Channel sites as a result of being located in side channels. Discharge values for the remaining sites will be obtained from gages located at Smartville and Marysville, depending on location relative to Daguerra Dam. Velocity sets have been collected for the transects at all eight study sites. Depth and velocity measurements were made using a boat-mounted ADCP and by wading with a wading rod equipped with a Marsh-McBirney^R model 2000 or a Price AA velocity meter. A tape or an electronic distance meter were used to measure stations along the transects. Substrate and cover along the transects were determined visually for all sites, with the exception of Narrows and Rose Bar sites, which have only been partially completed. Dry bed elevations and substrate and cover data along the transects have been collected, and vertical benchmarks have been tied together for all of the study sites.

We collected the data for between the up- and downstream transects by obtaining the bed elevation and horizontal location of individual points with a total station, while the cover and substrate were visually assessed at each point. Bed topography data collection has been completed, with the exception of the Narrows site and parts of the Rose Bar site. Collection of bed elevations, substrate and cover data for portions of the sites over 3 feet in depth using the ADCP and total station has been completed for all of the study sites, with the exception of Narrows site. All of the study sites, with the exception of the Narrows site, were shallow enough that the underwater video has not been needed to collect substrate and cover data; instead the substrate and cover data were directly visually determined. In the case of the Narrows site, bed elevations, substrate and cover data for portions of the site over three feet have been partially completed. The deep water conditions in the Narrows site required the use of underwater video to collect the substrate and cover data. Shallow validation velocity data collection for all of the eight study sites has been completed. We anticipate completing the hydraulic and structural data collection for all eight juvenile rearing study sites in early FY 2006.

Juvenile chinook salmon and steelhead/rainbow trout stranding sites

In FY 2005, 63 sites were located between the Narrows and the confluence with the Feather River where stranding flows for juvenile chinook salmon and steelhead/rainbow trout will be identified. Stage-discharge data collection was completed for 61 of the stranding sites. We completed stranding area data collection for 46 of the stranding sites. For smaller sites, we determined the area by measuring the length and two to six widths of the stranding site, using an electronic distance meter; the area is calculated by multiplying the length times the average width. The areas of larger site have been measured on aerial photos using a planimeter. We anticipate completing the stranding sites data collection in early FY 2006.

Hydraulic Model Construction and Calibration

Chinook salmon and steelhead/rainbow trout spawning

The topographic data for the 2-D model (contained in bed files) is first processed using the R2D_Bed software, where breaklines are added to produce a smooth bed topography. The resulting data set is then converted into a computational mesh using the R2D_Mesh software, with mesh elements sized to reduce the error in bed elevations resulting from the mesh-generating process to 0.1 foot where possible, given the computational constraints on the number of nodes. The resulting mesh is used in River2D to simulate depths and velocities at the flows to be simulated.

The Physical Habitat System (PHABSIM) transect at the downstream end of each site is calibrated to provide the Water Surface Elevation's (WSEL) at the downstream end of the site used by River2D. The PHABSIM transect at the upstream end of the site is calibrated to provide the water surface elevations used to calibrate the River2D model. The initial bed roughnesses used by River2D are based on the observed substrate sizes and cover types. A multiplier is applied to the resulting bed roughnesses, with the value of the multiplier adjusted so that the WSEL generated by River2D at the upstream end of the site match the WSEL predicted by the PHABSIM transect at the upstream end of the site[5]. The River2D model is run at the flows at which the validation data set was collected, with the output used in GIS to determine the difference between simulated and measured velocities, depths, bed elevations, substrate and cover. The River2D model is also run at the simulation flows to use in computing habitat.

All data for the 10 spawning sites have been compiled and checked. PHABSIM data decks and hydraulic calibration have been completed for the upstream and downstream transects for all ten sites. Bed files have been partially completed for four sites. Construction and calibration of the 2-D models and production runs for all ten spawning sites will be completed in FY 2006.

Juvenile chinook salmon and steelhead/rainbow trout rearing

Data for the eight rearing sites are in the process of being compiled and checked. PHABSIM data decks have been created and hydraulic calibration has been completed for the upstream and downstream transects for two of the rearing sites. We anticipate completing the hydraulic calibration, bed files, computational meshes for the 2-D modeling program, calibration of the two-dimensional hydraulic models, and production runs for all of the simulation flows for the eight rearing sites in FY 2006.

---

[5] This is the primary technique used to calibrate the River2D model.

Juvenile chinook salmon stranding areas

We anticipate completing the determination of stranding flows and stranding areas for the 63 stranding sites in FY 2006, and a draft report should be completed by September 2006.

Habitat Suitability Criteria Development

Chinook salmon and steelhead/rainbow trout spawning

Data collection for fall and spring-run chinook salmon and steelhead/rainbow trout spawning criteria was completed in FY 2004. Work on developing fall and spring-run chinook salmon and steelhead/rainbow trout spawning criteria began in FY 2005 and should be completed in FY 2006.

Juvenile chinook salmon and steelhead/rainbow trout rearing

The collection of Young of Year (YOY) chinook salmon and steelhead/rainbow trout (fry and juveniles) rearing HSC data continued during FY 2005 with surveys conducted on November 15-18, 2004, December 13-16, 2004, February 7-10, 2005, July 11-14, 2005, August 8-11, 2005, and September 6-9, 2005. We spent particular effort on getting observations of YOY > 60 mm, since we had so few observations of these larger fish at the end of FY 2004. Snorkel surveys were mostly conducted along the banks, although in a few cases we snorkeled the entire width of the river. Only one SCUBA survey in deeper water was conducted. We also collected depth, velocity, adjacent velocity[6] and cover data on locations which were not occupied by YOY chinook salmon and steelhead/rainbow trout (unoccupied locations). This was done so that we could apply a method presented in Rubin et. al. (1991) to explicitly take into account habitat availability in developing HSC criteria, without using preference ratios (use divided by availability). Traditionally, criteria are created from observations of fish use by fitting a nonlinear function to the frequency of habitat use for each variable (depth, velocity, cover,

---

[6] The adjacent velocity was measured within 2 feet on either side of the location where the velocity was the highest. Two feet was selected based on a mechanism of turbulent mixing transporting invertebrate drift from fast-water areas to adjacent slow-water areas where fry and juvenile salmon and steelhead/rainbow trout reside, taking into account that the size of turbulent eddies is approximately one-half of the mean river depth (Terry Waddle, USGS, personal communication), and assuming that the mean depth of the Yuba River is around 4 feet (i.e., 4 feet x ½ = 2 feet). This measurement was taken to provide the option of using an alternative habitat model which considers adjacent velocities in assessing habitat quality. Adjacent velocity can be an important habitat variable as fish, particularly fry and juveniles, frequently reside in slow-water habitats adjacent to faster water where invertebrate drift is conveyed. Both the residence and adjacent velocity variables are important for fish to minimize the energy expenditure/food intake ratio and maintain growth.

adjacent velocity). One concern with this technique is what effect the availability of habitat has on the observed frequency of habitat use. For example, if cover is relatively rare in a stream, fish will be found primarily not using cover simply because of the rarity of cover, rather than because they are selecting areas without cover. Rubin et. al. (1991) proposed a modification of the above technique where habitat suitability criteria data are collected both in locations where fish are present and in locations where fish are absent. Criteria are then developed by using a nonlinear regression procedure (suited to data with a Poisson distribution) with number of fish as the dependent variable and depth, velocity, cover and adjacent velocity as the independent variables, and all of the data (in both occupied and unoccupied locations) are used in the regression. An alternative approach is to use a logistic regression procedure, with the only difference being that the dependent variable is the presence or absence of fish.

Before going out into the field, a data book was prepared with one line for each unoccupied location where depth, velocity, cover and adjacent velocity would be measured. Each line had a distance from the bank, with a range of 0.5 to 10 feet by 0.5 foot increments, with the values produced by a random number generator. In areas where we were able to sample up to 20 feet from the bank, we doubled the above distances.

When conducting snorkel surveys adjacent to the bank, one person snorkeled upstream along the bank and placed a weighted, numbered tag at each location where YOY chinook salmon or steelhead/rainbow trout were observed. The snorkeler recorded the tag number, the species, the cover code[7] and the number of individuals observed in each 10-20 mm size class on a Poly Vinyl Chloride (PVC) wrist cuff. Water temperature, the average and maximum distance from the water's edge that was sampled, cover availability in the area sampled (percentage of the area with different cover types) and the length of bank sampled (measured with a 300-foot-long tape) was also recorded. The cover coding system used is shown in Table 1.

A 300-foot-long tape was put out with one end at the location where the snorkeler finished and the other end where the snorkeler began. Three people went up the tape, one with a stadia rod and data book and the other two with a wading rod and velocity meter. At every 20-foot interval along the tape, the person with the stadia rod measured out the distance from the bank given in the data book. If there was a tag within 3 feet of the location, "tag within 3" was recorded on that line in the data book and the people proceeded to the next 20-foot mark on the tape, using the distance from the bank on the next line. If the location was beyond the sampling distance, based on the information recorded by the snorkeler, "beyond sampling distance" was recorded on that line and the recorder went to the next line at that same location, repeating until reaching a line with a distance from the bank within the sampling distance. If there was no tag within 3 feet of that location, one of the people with the wading rod measured the depth, velocity, adjacent velocity and cover at that location. Depth was recorded to the nearest 0.1 foot and average water

[7] If there was no cover elements (as defined in Table 1) within 1 foot horizontally of the fish location, the cover code was 0.1 (no cover).

column velocity and adjacent velocity were recorded to the nearest 0.01 feet/second. Another individual retrieved the tags, measured the depth and mean water column velocity at the tag location, measured the adjacent velocity for the location, and recorded the data for each tag number. Data taken by the snorkeler and the measurer were correlated at each tag location.

One scuba survey of deep water mesohabitat was conducted by first anchoring a rope longitudinally upstream through the area to be surveyed to facilitate upstream movement by the

Table 1
Cover Coding System

Cover Category	Cover Code[8]
no cover	0.1
cobble (3-12" diameter)	1
boulder (> 1' diameter)	2
fine woody vegetation (< 1" diameter)	3
branches	4
log (> 1' diameter)	5
overhead cover (> 2' from substrate)	7
undercut bank	8
aquatic vegetation	9
rip-rap	10

divers and increase diver safety. Two divers entered the water at the downstream end of the rope and proceeded along the rope upstream using climbing ascenders. One diver concentrated on surveying the water below and to the side, while the other diver concentrated on surveying the water above and to the side. When a YOY salmon or steelhead/rainbow trout was observed, a weighted buoy was placed by the divers at the location of the observation. The cover code and the number of individuals observed in each 10-20 mm size class was then recorded on a PVC wrist cuff. Water temperature, cover availability in the area sampled (percentage of the area with different cover types) and the length of river sampled (measured with the electronic distance meter) were also recorded.

[8] In addition to these cover codes, we have been using the composite cover codes 3.7, 4.7, 5.7 and 9.7; for example, 4.7 would be branches plus overhead cover.

After the dive was completed, the ADCP was turned on (to record unoccupied depth and velocity data) as we started to pull in the rope after the dive. The boat followed the course of the dive as the rope was pulled back into the boat. If there were any observations during the dive, the ADCP was stopped 3 feet before the location of the observation and started again 3 feet after the location of the observation. For each occupied location, individuals in the boat retrieved each buoy and measured the water velocity and depth over that location with the ADCP, making at least 12 observations. For each set of data collected using the ADCP for a juvenile fish observation, the average depth and velocity are considered the depth and velocity, while the maximum velocity is considered the adjacent velocity. The ADCP was turned off at the location where the dive ended. For the one SCUBA survey that was done in FY 2005, no unoccupied data was collected.

SCUBA surveys of deeper habitat units, which have been conducted in previous years of this study, were eliminated in FY 2005, with the exception of one survey in August 2005. The decision to eliminate the SCUBA surveys was made given the amount of time required for the SCUBA surveys and the small numbers of observations made using this method. Given that a significant number of observations of juvenile steelhead/rainbow trout and spring/fall-run chinook salmon 60 mm or greater in size were still needed, we determined that devoting all available survey time to snorkeling surveys was the needed to achieve the number of observations required to develop juvenile rearing HSC.

All YOY chinook salmon observed have been classified by race according to a table provided by CDFG correlating race with life stage periodicity and total length. However, based on Earley and Brown (2004) and McReynolds et al.'s (2004) findings that most known spring-run chinook salmon YOY from Sacramento River tributaries would be classified as fall-run by the CDFG race table, we are considering all YOY classified by the race table as fall-run to be spring/fall-run. It is likely we would find the same results as Earley and Brown (2004) and McReynolds et al. (2004) for the Yuba River, since we have only had two observations (both yolk-sac fry) which were classified as spring-run by the CDFG race tables. Data were also compiled on the length of each mesohabitat and cover type sampled to try to have equal effort in each mesohabitat and cover type and that each location was only sampled once at the same flow (to avoid problems with pseudo-replication).

Results

In FY 2005, we collected a total of 116 measurements of cover, depth, velocity and adjacent velocity where YOY steelhead/rainbow trout and fall/spring-run chinook salmon were observed (in two cases, fall/spring-run chinook salmon and steelhead/rainbow trout were in the same observation). There were 72 observations of YOY fall/spring-run chinook salmon, and 46 observations of YOY steelhead/rainbow trout. Of the 72 YOY fall/spring-run chinook salmon observations, 14 observations were made downstream of Daguerra Dam and 58 observations were made upstream of Daguerra Dam, with all observations made near the river banks while snorkeling. There were 10 YOY spring/fall-run chinook salmon observations of <40 mm fish, 39 observations of 40-60 mm fish, 15 observations of 60-80 mm fish, and 11 observations of >80 mm fish[9]. Of the 46 observations of YOY steelhead/rainbow trout, 19 observations were made downstream of Daguerra Dam and 27 observations were made upstream of Daguerra Dam. All of these observations, with the exception of 4, were made near the river banks while snorkeling. Of the four observations made away from the banks, two observations occurred during the single SCUBA survey conducted in FY 2005, and two observations were made while snokeling the entire width of the channel. Of the 46 YOY steelhead/rainbow trout observations, there were 0 observations of < 40 mm fish, 0 observations of 40-60 mm fish, 27 observations of 60-80 mm fish and 20 observations of fish greater than 80 mm. The reason for the being zero observations for the <40 mm and 40-60 mm size classes was that we already had enough observations for steelhead/rainbow trout for these size classes and only made observations on juvenile steelhead/rainbow trout 60 mm or larger. We made 380 measurements for unoccupied locations. Depth, velocity and adjacent velocity were measured at all 380 locations, and cover was recorded at all of the locations.

A total of 37 mesohabitat units (22 upstream of Daguerra Dam and 24 downstream of Daguerra Dam) were surveyed in FY 2005. A total of 7,245 feet of near-bank habitat and 1,600 feet of mid-river habitat were sampled in FY 2005. Table 2 summarizes the number of feet of different mesohabitat types sampled in FY 2005 and Table 3 summarizes the number of feet of different cover types sampled in FY 2005.

We have developed two different groups of cover codes based on snorkel surveys we conducted on the Sacramento River: Cover Group 1 (cover codes 4 and 7 and composite [instream+overhead] cover), and Cover Group 0 (all other cover codes). We sampled 4,950 feet of Cover Group 0 and 2,295 feet of Cover Group 1 in near-bank habitat (snorkeling), and sampled 1,374 feet of Cover Group 0 and 226 feet of Cover Group 1 in mid-channel habitat (SCUBA and snorkeling). The collection of chinook salmon and steelhead/rainbow trout fry and juveniles (YOY) rearing HSC data was completed in FY 2005. We anticipate completing development of fall and spring-run chinook salmon and steelhead/rainbow trout juvenile rearing criteria in FY 2006.

---

[9] These numbers total more than 143 because most of the observations included YOY of several size classes and only one measurement was made per group of closely associated individuals.

Table 2
FY 2005 Distances (feet) Sampled for YOY Salmonid HSC Data - Mesohabitat Types

Mesohabitat Type	Near-bank habitat distance sampled	Mid-channel habitat distance sampled
Bar Complex Glide	1480	0
Bar Complex Pool	400	0
Bar Complex Riffle	100	0
Bar Complex Run	3665	0
Flatwater Glide	100	0
Flatwater Pool	200	1500
Flatwater Riffle	0	0
Flatwater Run	100	0
Side-Channel Glide	300	0
Side-Channel Pool	0	100
Side-Channel Riffle	0	0
Side-Channel Run	900	0

Table 3
FY 2005 Distances (feet) Sampled for Juvenile Salmonid HSC Data - Cover Types

Cover Type	Near-bank habitat distance sampled	Mid-channel habitat distance sampled
None	1867	50
Cobble	1834	60
Boulder	838	1208
Fine Woody	1482	1
Branches	605	1
Log	170	75
Overhead	416	150
Undercut	0	0
Aquatic Vegetation	15	0
Rip Rap	20	0
Overhead + instream	1648	1

Habitat Simulation

Chinook salmon and steelhead/rainbow trout spawning

Spring/fall-run chinook salmon and steelhead/rainbow trout spawning habitat will be computed over a range of discharges in FY 2006 for the 10 spawning study sites. A draft report on flow-habitat relationships for spawning should be completed by September 2006.

Juvenile chinook salmon and steelhead/rainbow trout rearing

Spring/fall-run chinook salmon and steelhead/rainbow trout fry and juvenile rearing habitat will be computed over a range of discharges in FY 2005 for the eight rearing study sites. A draft report on flow-habitat relationships for rearing should be completed by September 2006.

CLEAR CREEK

Habitat Mapping

Mesohabitat mapping of Clear Creek was conducted in August and September of 2004 by biologists from the North Central Valley Fish and Wildlife Office for the Upper Alluvial and Canyon Reaches, which comprise approximately 3.5 miles of Clear Creek between Whiskeytown Dam and Clear Creek Road. The mesohabitat mapping in the annual work plan called for either using aerial photos or on-the-ground methods using an electronic distance meter and Global Positioning System (GPS) unit to determine the total length of each mesohabitat type (run, riffle, pool, glide) and the location of each mesohabitat unit. In October 2004, we accompanied the biologists that had conducted the mesohabitat mapping in a reconnaissance of the mesohabitats identified for the Upper Alluvial Reach to help verify that the mesohabitat mapping process had been done to our specifications.

The mesohabitat mapping consisted of snorkeling and walking downstream from Whiskeytown Dam and delineating the mesohabitat units. Using habitat typing protocols developed by CDFG, the Yuba River was habitat mapped between the Whiskeytown Dam and Clear Creek Road Bridge. Aerial photos were used in conjunction with direct observations to determine the beginning and ending of each habitat unit. The length of each mesohabitat unit was measured using a laser range finder or a tape measure if the unit was less than 12 feet in length. The mesohabitat units were delineated on the aerial photos. The number of units for each habitat type were determined for each reach. A total of 74 mesohabitat units were mapped for the Upper Alluvial Reach and 202 mesohabitat units for the Canyon Reach. Table 4 summarizes the mesohabitat types, length totals and numbers of each type recorded during the habitat mapping process.

Field Reconnaissance and Study Site Selection

Juvenile spring-run chinook salmon and steelhead/rainbow trout rearing

The first rearing phase of work encompasses the Upper Alluvial and Canyon Reaches. These are the same reaches where the first phase spawning habitat study sites are located and where spring-run chinook salmon and steelhead/rainbow trout are known to spawn. Field reconnaissance in the November 2005 and February 2005 investigated potential study sites in these two reaches. Field reconnaissance of potential study sites was limited by the ability to access the creek and safety considerations. Based on the results of the mesohabitat mapping and the field reconnaissance, a list of the potential study sites was developed. A number of the potential study sites on this list were eliminated based on access difficulty and safety considerations. Using the final list of potential study sites, we selected six habitat study sites that, together with the six spawning habitat study sites, will represent the habitat types found in the same two reaches as the first phase spawning sites. We attempted to randomly selected the six new habitat study sites from those areas that were found to have reasonable and safe access to insure unbiased selection

Table 4
FY 2005 Clear Creek Mesohabitat Mapping Results by Reach

Mesohabitat Type	Upper Alluvial Units Length Totals (ft)	Upper Alluvial Number of Units	Canyon Units Length Totals (ft)	Canyon Number of Units
Side Channel Pool	20	1	0	0
Mid Channel Pool	1385	16	7876	76
Side Channel Riffle	132	6	63	2
Mid Channel Riffle	1123	21	2054	46
Side Channel Run	151	6	20	2
Mid Channel Run	1217	19	1968	41
Side Channel Glide	136	2	0	0
Mid Channel Glide	56	2	151	5
Side Channel Cascade	20	1	0	0
Mid Channel Cascade	0	0	1592	31

of the study sites. However, upon revisiting two of the selected sites in preparation for study site set-up, it was determined that the extreme difficulty in accessing the sites and the amounts of poison oak present around the sites made data collection unpractical and unsafe. As a result, two other study sites were selected as replacements. The following is the finalized list of the six study sites, listed in order from upstream to downstream by reach. Upper Alluvial Reach: Dog Gulch; Canyon Reach: Upper Canyon, Narrows, Kanaka, Above IGO, and Upper Placer Extension. The presence of only one study site in the Upper Alluvial Reach was the result of the spawning sites in that reach having already adequately represented most of the habitat types for that reach.

Transect Placement (study site setup)

Juvenile spring-run chinook salmon and steelhead/rainbow trout rearing

Five of the six study sites were established in June 2005. The Above IGO site was established in August 2005. For the sites selected for modeling, the landowners along both riverbanks were identified and temporary entry permits were sent, accompanied by a cover letter, to acquire permission for entry onto their property during the course of the study.

For each study site, a transect has been placed at the up- and downstream ends of the site. The downstream transect will be modeled with PHABSIM to provide water surface elevations as an input to the 2-D model. The upstream transect will be used in calibrating the 2-D model. The initial bed roughnesses used by River2D are based on the observed substrate sizes and cover types. A multiplier is applied to the resulting bed roughnesses, with the value of the multiplier adjusted so that the WSEL generated by River2D at the upstream end of the site match the WSEL predicted by the PHABSIM transect at the upstream end of the site. Transect pins (headpins and tailpins) were marked on each river bank above the 1,000 cfs water surface level using rebar driven into the ground and/or bolts placed in tree trunks. Survey flagging was used to mark the locations of each pin. In August 2005, the downstream transect of Upper Canyon site was re-established as a result of plans for gravel injection in the vicinity of the original downstream transect location. The downstream transect was moved upstream to a location where influences of the gravel injection on water surface elevations and bed topography would be avoided. However, this significantly reduced the length of creek comprising the study site and significantly reduced the amount of riffle habitat that was to be modeled for that site.

Hydraulic and Structural Data Collection

Spring-run chinook salmon and steelhead/rainbow trout spawning

Hydraulic and structural data collection continued and was completed in FY 2005. Low, medium and high flow water surface elevations were collected for all six sites. Velocity sets were collected for the transects at all six study sites. Depth and velocity measurements were made by wading with a wading rod equipped with a Marsh-McBirney[R] model 2000 or a Price AA velocity meter. A tape or an electronic distance meter were used to measure stations along the transects. Substrate and cover along the transects were determined visually. Dry bed elevations and substrate and cover data along the transects were collected and the vertical benchmarks were tied together at all six sites.

We collected the data between the up- and downstream transects by obtaining the bed elevation and horizontal location of individual points with a total station, while the cover and substrate was visually assessed at each point. Bed topography data collection was completed for the six study sites. Validation velocity data collection for all six study sites was completed. Stage of zero flow at the downstream transect was surveyed in for all six sites.

Juvenile spring-run chinook salmon and steelhead/rainbow trout rearing

Vertical benchmarks (lagbolts in trees or bedrock points) were established and water surface elevations collected at all six spawning sites at low flows (~125 cfs). Water surface elevations have been collected at medium flows (~ 200 cfs) at Dog Gulch, Upper Canyon, Narrows, Kanaka, and Upper Placer Extension study sites. The vertical benchmark elevations have been tied-in for Dog Gulch, Narrows, Kanaka, and Upper Placer Extension study sites.

We collected the data between the up- and downstream transects by obtaining the bed elevation and horizontal location of individual points with a total station, while the cover and substrate were visually assessed at each point. Bed topography data collection has been completed for the Above IGO site. We anticipate completing the hydraulic and structural data collection for the six rearing sites in FY 2006. We then anticipate proceeding with the selection of spawning and rearing study sites in the Lower Alluvial Reach and beginning structural and hydraulic collection for those sites by September 2006.

Hydraulic Model Construction and Calibration

Spring-run chinook salmon and steelhead/rainbow trout spawning

The topographic data for the 2-D model (contained in bed files) is first processed using the R2D_Bed software, where breaklines are added to produce a smooth bed topography. The resulting data set is then converted into a computational mesh using the R2D_Mesh software, with mesh elements sized to reduce the error in bed elevations resulting from the mesh-generating process to 0.1 foot where possible, given the computational constraints on the number of nodes. The resulting mesh is used in River2D to simulate depths and velocities at the flows to be simulated.

The PHABSIM transect at the downstream end of each site is calibrated to provide the WSEL at the downstream end of the site used by River2D. The PHABSIM transect at the upstream end of the site is calibrated to provide the water surface elevations used to calibrate the River2D model.

The initial bed roughnesses used by River2D are based on the observed substrate sizes and cover types. A multiplier is applied to the resulting bed roughnesses, with the value of the multiplier adjusted so that the WSEL generated by River2D at the upstream end of the site match the WSEL predicted by the PHABSIM transect at the upstream end of the site[10]. The River2D model is run at the flows at which the validation data set was collected, with the output used in GIS to determine the difference between simulated and measured velocities, depths, bed elevations, substrate and cover. The River2D model is also run at the simulation flows to use in computing habitat.

Construction and calibration of the 2-D models and production runs for all of the simulation flows were completed for all six study sites in FY 2005.

Habitat Suitability Criteria Development

Spring-run Chinook Salmon and Steelhead/Rainbow Trout Spawning

Staff of the Red Bluff Fish and Wildlife Office have been collecting spring-run chinook salmon and steelhead/rainbow trout spawning habitat suitability criteria during their biweekly snorkel surveys of Clear Creek. For HSC data collection, all of the active redds (those not covered with periphyton growth) which could be distinguished were measured. The location of each redd was marked with a GPS unit. The location of each redd found in our study site was determined with a total station. Data were collected from an area adjacent to the redd which was judged to have a similar depth and velocity as was present at the redd location prior to redd construction. This location was generally about 2 to 4 feet upstream of the pit of the redd; however it was sometimes necessary to make measurements at a 45 degree angle upstream, to the side, or behind the pit. The data were almost always collected within 6 feet of the pit of the redd. Depth was recorded to the nearest 0.1 foot (ft) and average water column velocity was recorded to the nearest 0.01 ft/second. Substrate was visually assessed for the dominant particle size range (i.e., range of 1-2 inches) at three locations: 1) in front of the pit; 2) on the sides of the pit; and 3) in the tailspill. Substrate embeddedness data were not collected because the substrate adjacent to all of the redds sampled was predominantly unembedded. The substrate coding system used is shown in Table 5. Since data were collected within 2 weeks of redd construction (as a result of the biweekly surveys) it is likely that the measured depths and velocities on the redds are similar to those present during redd construction. To date, complete HSC data (depth, velocity and substrate) have been collected on 94 spring-run chinook salmon redds and 224 steelhead/rainbow trout redds. HSC spawning data collection for spring-run chinook salmon and steelhead/rainbow trout will continue in FY 2006.

[10] This is the primary technique used to calibrate the River2D model.

Table 5
Substrate Descriptors and Codes

Code	Type	Particle Size (inches)
0.1	Sand/Silt	< 0.1
1	Small Gravel	0.1 - 1
1.2	Medium Gravel	1 - 2
1.3	Medium/Large Gravel	1 - 3
2.4	Gravel/Cobble	2 - 4
3.5	Small Cobble	3 - 5
4.6	Medium Cobble	4 - 6
6.8	Large Cobble	6 - 8
8	Large Cobble	8 - 10
9	Boulder/Bedrock	> 12
10	Large Cobble	10-12

Juvenile spring-run chinook salmon and steelhead/rainbow trout rearing

The collection of spring-run chinook salmon and steelhead/rainbow YOY rearing HSC data began during FY 2005. Staff of the Red Bluff Fish and Wildlife Office have been collecting spring-run chinook salmon and steelhead/rainbow trout spawning habitat suitability criteria during their biweekly snorkel surveys of Clear Creek, when YOY are observed. In addition, snorkeling surveys have been conducted specifically to collect rearing HSC. The methods used are similar to those described previously for the Yuba River rearing study, although SCUBA is not being employed on Clear Creek. There have been some modifications to the protocols that were used on the Yuba River. These modifications are described as follows:

If one person was snorkeling per habitat unit, the side of the creek to be snorkeled would alternate with each habitat unit and would also include snorkeling the middle portion of some units. As an example, the right bank was snorkeled for one habitat unit, the middle of the next habitat unit was then snorkeled, and then the left bank was snorkeled of the next habitat unit and then the process was repeated. The Sacramento Fish and Wildlife Office Instream Flow Group designates left and right bank looking upstream. The habitat units were snorkeled working upstream, which is generally the standard for snorkel surveys. In some cases when snorkeling the middle of a habitat unit, the difficulty of snorkeling mid-channel required snorkeling downstream. To collect the unoccupied data for the mid-channel snorkel surveys, the distance to be snorkeled was established by laying out the tape on a bank next to the distance of creek that was to be snorkeled. After snorkeling that distance, the line snorkeled was followed down through the middle of the channel and the randomly selected distance at which the unoccupied data was to be collected was measured out toward the left or right bank, alternating with each 10 foot location along the tape. Otherwise, for snorkeling that occurred along the left and right banks, the same protocols as described for the Yuba River snorkeling occupied and unoccupied measurements were applied.

If three people were going to snorkel each unit, one person snorkeled along each bank working upstream, while the third person snorkeled downstream through the middle of the unit. The distance to be snorkeled was delineated by laying out a tape along the bank as described previously for a distance of 150 feet or 300 feet. Unoccupied data was collected for each habitat unit snorkeled in this manner by alternating left and right bank or mid-channel for each habitat unit snorkeled. As an example, for the first habitat unit snorkeled, unoccupied data would be collected along the left bank. At the next unit, data would be collected along the right bank. At the next unit, the data would be collected as described previously using the mid-channel line snorkeled. When three people were snorkeling, cover percentages were collected by each person snorkeling. After completing each unit, the percentages for each person were combined and averaged.

To date, there have been 12 observations of YOY spring-run chinook salmon, and 37 observations of YOY steelhead/rainbow trout (in this case the use of the term observations indicates when a sighting of one or more fish occurred. An observation can include observations of fry (<60 mm in length) and observations of juveniles (≥60 mm)). Of the 13 YOY spring-run chinook salmon observations, there have been 5 spring-run chinook salmon observations of <60 mm fish and 8 spring-run chinook salmon observations of ≥60 mm fish. Of the 37 YOY steelhead/rainbow trout observations, there have been 86 steelhead/rainbow trout observations of <60 mm fish and 34 steelhead/rainbow trout observations of ≥60 mm fish. HSC juvenile rearing data collection for spring-run chinook salmon and steelhead/rainbow trout will continue in FY 2006.

Habitat Simulation

Spring-run chinook salmon and steelhead/rainbow trout spawning

Once sufficient spring-run chinook salmon and steelhead/rainbow trout spawning HSC data have been collected and spawning criteria have been developed, spring-run chinook salmon and steelhead/rainbow trout spawning habitat will be computed over a range of discharges for the six spawning sites. Completion of this phase of the study and completion of the draft report will be subject to the time required to collect sufficient spring-run chinook salmon and steelhead/rainbow trout spawning HSC data.

Juvenile spring-run chinook salmon and steelhead/rainbow trout rearing

Once sufficient spring-run chinook salmon and steelhead/rainbow trout juvenile rearing HSC data have been collected and rearing criteria have been developed, spring-run chinook salmon and steelhead/rainbow trout spawning habitat will be computed over a range of discharges for the six spawning sites. Completion of this phase of the study and completion of the draft report will be subject to the time required to collect sufficient spring-run chinook salmon and steelhead/rainbow trout spawning HSC data. Given the small number of observations of juvenile spring-run chinook salmon and steelhead/rainbow trout gathered to date, it may be necessary to utilize spring-run chinook salmon and steelhead/rainbow trout juvenile rearing HSC data from another creek or river with characteristics similar to Clear Creek or conduct transferability tests using rearing HSC from another creek or river.

REFERENCES

Earley, J.T. and M. Brown. 2004. Accurately estimating abundance of juvenile spring chinook salmon in Battle and Clear Creeks. In: Getting Results: Integrating Science and Management to Achieve System-Level Responses. 3rd Biennial CALFED Bay-Delta Program Science Conference Abstracts. October 4-6, 2004. Sacramento, CA.

McReynolds, T., P. Ward and C. Harvey-Arrison. 2004. Utility of juvenile salmon growth models for discrimination of Central Valley spring-run chinook in California. In: Getting Results: Integrating Science and Management to Achieve System-Level Responses. 3rd Biennial CALFED Bay-Delta Program Science Conference Abstracts. October 4-6, 2004. Sacramento, CA.

Rubin, S.P., T.C. Bjornn and B. Dennis. 1991. Habitat suitability curves for juvenile chinook salmon and steelhead development using a habitat-oriented sampling approach. Rivers 2(1):12-29.

U. S. Fish and Wildlife Service. 1999. Hydraulic modeling of chinook salmon spawning sites in the Sacramento River between Keswick Dam and Battle Creek. U. S. Fish and Wildlife Service, Sacramento, CA.

U. S. Fish and Wildlife Service, 2000. Effects of the January 1997 flood on flow-habitat relationships for steelhead and fall-run chinook salmon spawning in the Lower American River. U. S. Fish and Wildlife Service, Sacramento, CA.

U. S. Fish and Wildlife Service. 2003. Flow-habitat relationships for steelhead and fall, late-fall and winter-run chinook salmon spawning in the Sacramento River between Keswick Dam and Battle Creek.